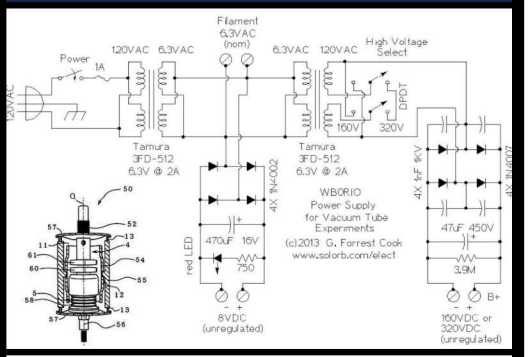

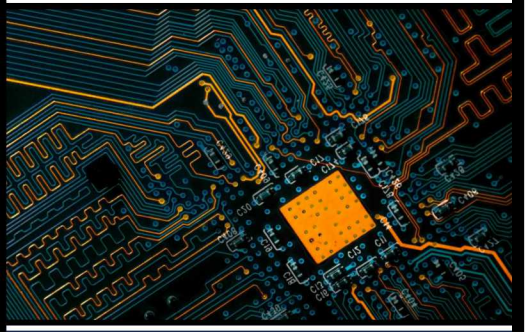

SAND2019-3542PE

Standardization of High Voltage Component Research and Development

Sandia National Laboratories

Jakub Mroczkowski

EMGT 590: Final Project

4/24/2019

U.S. DEPARTMENT OF ENERGY NNSA

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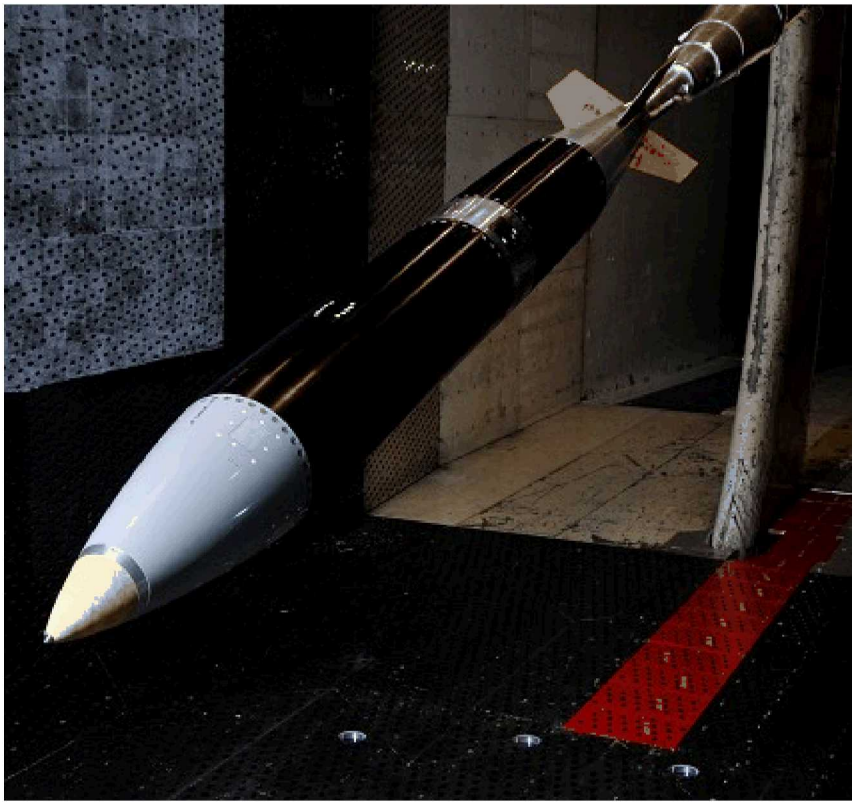
SAND2018-1047 PE

Outline/Overview

- Introduction
  - HVCO
  - Product Realization
- Research Background
  - Circuit R&D
  - Custom Process
  - Standardized Process
- Methodology
- Computational Results
  - SM Performance
  - Business Impact
- Conclusion



Introduction

- Sandia National Laboratories
  - Research & development lab
  - National Nuclear Security Administration
  - Development, design, and testing of non-nuclear components for nuclear weapons
  - Federal Funded Research & Development Center
- Mission Focus:
  - “…anticipating and resolving emerging national security challenges, innovating and discovering new technologies to strengthen the nation's technological superiority, creating value through products and services that solve important national security challenges, and informing the national debate where technology policy is critical to preserving security and freedom throughout our world."

HVCO

- Sub-organization
  - Specializing in a custom technology that has no commercial-off-the-shelf (COTS) variants requires the organization to be the sole entity for not only R&D, but for reliability confirmation, product support, troubleshooting, and quality assurance.
  - Depending on the application and specific configurations that the "product" must meet, the "product" is designed based on criteria provided by the "customer" to full-fill the order.
  - “Product" is tested and verified in a simulator through a modeled circuit that mimics the intended use in order to meet "customer" needs while also certifying quality control of a reliable "product" to deliver.

Product Realization

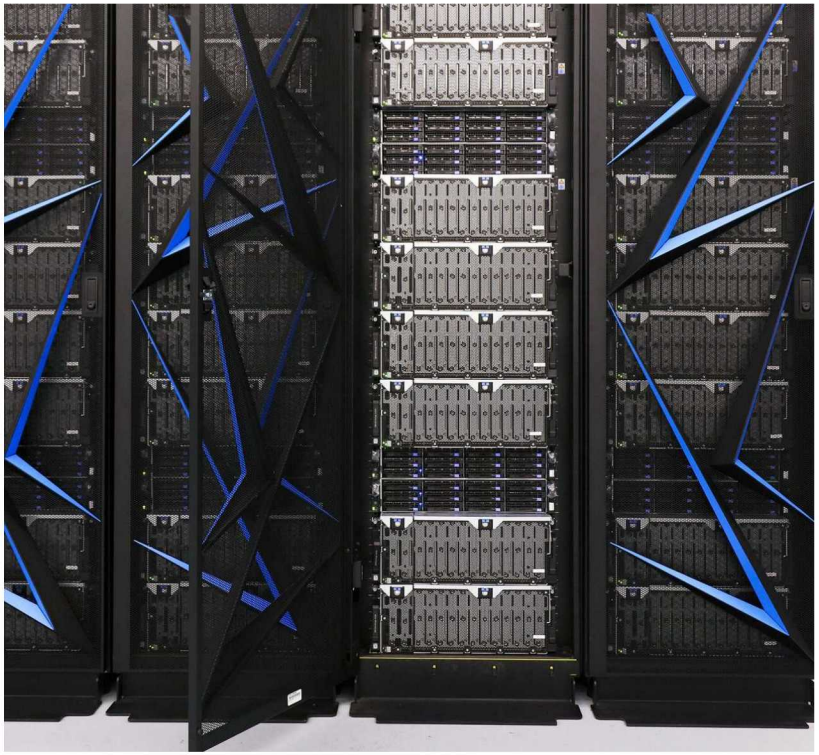
- Testing custom HV components
  - While each "product" may be unique for performing in a manner related to the intended circuit function provided for by the "customer", the method of testing the "product" consists of the same simulators that trigger and record performance characteristics of the high voltage component in the circuit applied.
  - While not only being responsible for current "product" developed or in production, legacy products previously developed are additional projects that are addressed.
  - Prior "products" have a lack of documentation that results in additional R&D to be performed in order to re-engineer and understand the previous "product" itself.

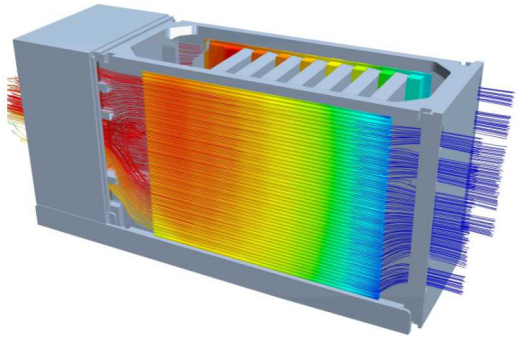
Research Background

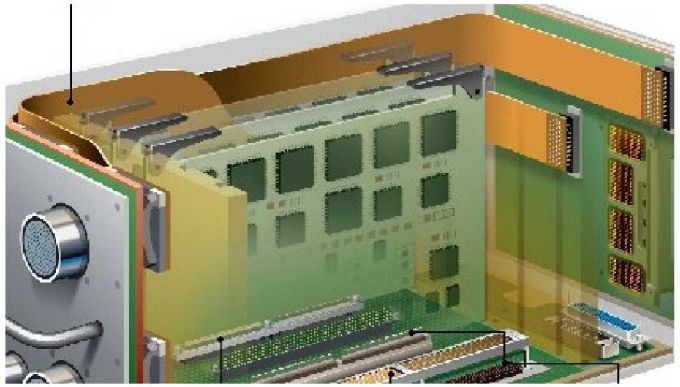
- Business model is not parallel to most businesses' objectives
  - Industry vs. HVCO (Sandia)
  - Cutting costs
  - Maximize profits
  - Competition
- Operating as a FFRDC
  - Government guaranteed funding
  - "Exceptional service in the national interest"
  - Demand for innovation and advancing technology while maintaining national security
  - Maximizing R&D

Circuit R&D

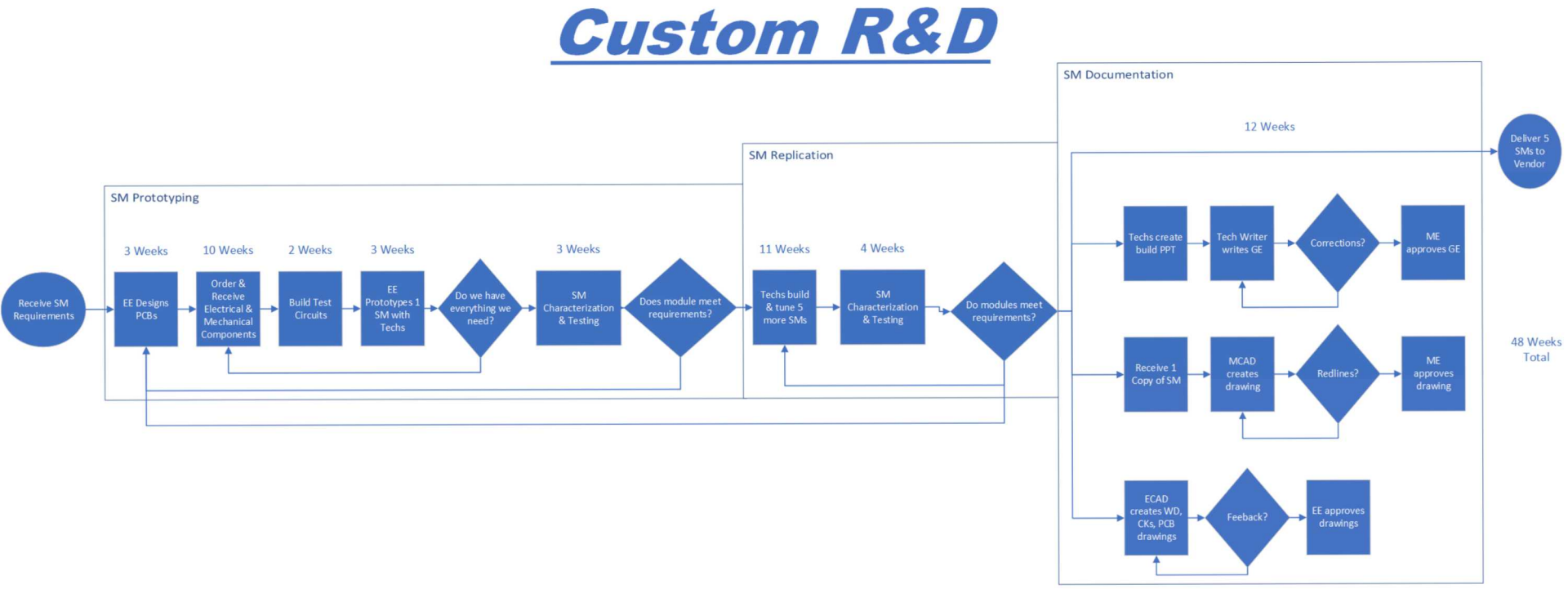
- Opportunity to stress more time for R&D over regular "customer service" is desired by the organization.
- Reduce time and costs
- Increase performance



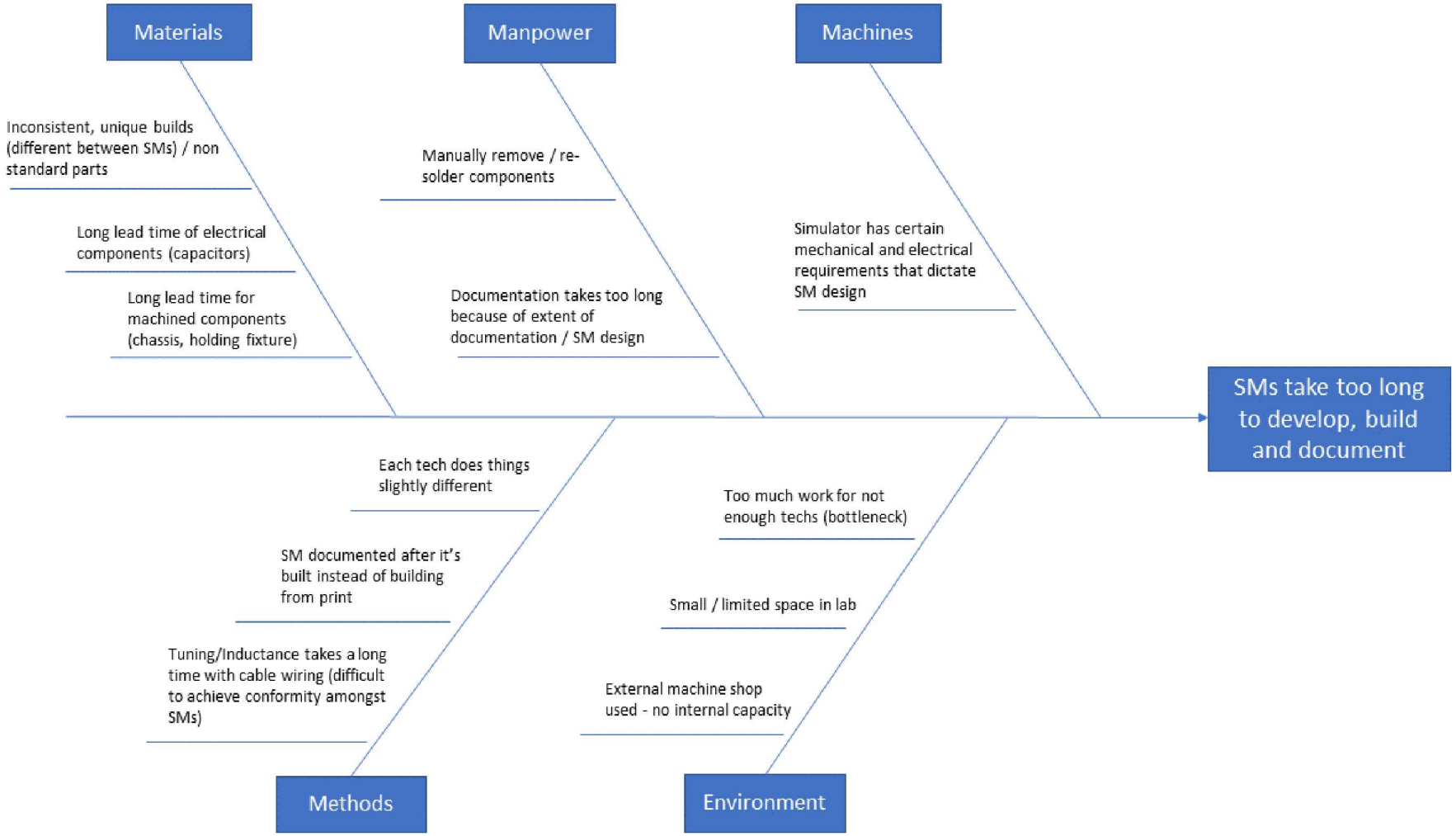




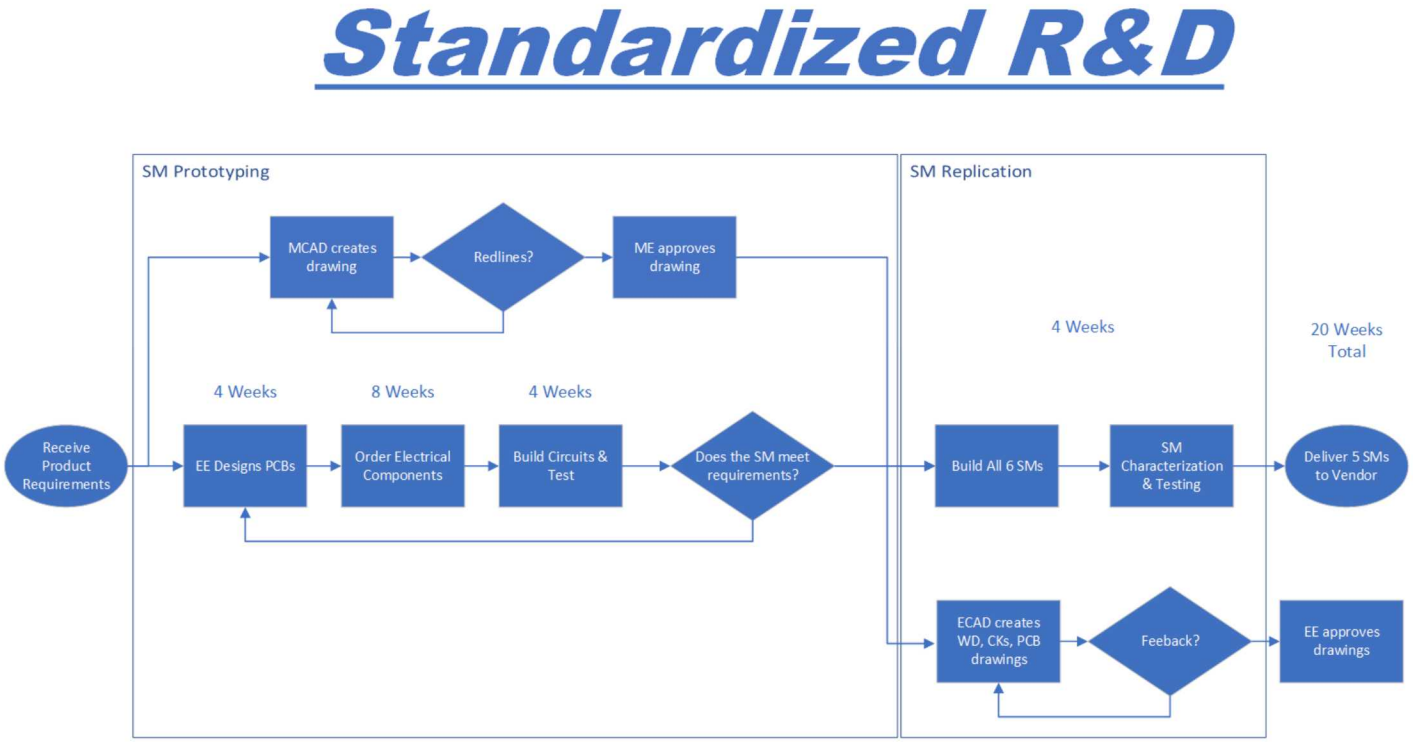
Custom Design



Custom Design: Identifying Issue



Standardized Design



Comparison

- Shorter lead time
- Waste & Variation
  - Redundant circuit design
  - Time, waiting for custom components and waiting for available technologist
  - Over-Processing, solder connections and custom solutions unnecessary
  - Defects, SMs need re-build after extended use
- Dependency's
  - Module Design
  - Materials Procurement
  - Technologist work overload

- Streamline SM development
- Reduce planning and documentation efforts.
- Reduce SM assembly time & allow techs/engineers to focus on other research and development areas.

Methodology

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Descriptive Statistics

$$Mean: \mu = \frac{1}{n}\sum x_i$$

$$Variance: \sigma^2 = \frac{1}{n}\sum (x_i - \bar{x})^2$$

$$Standard\ Deviation: \sigma = \frac{1}{n}\sum (x_i - \bar{x})^2$$

Hypothesis Test: tests the claim or statement about a property of a population $\mu \neq \mu_0$

$$\overline{X_n} = \frac{x_n}{n_n}$$

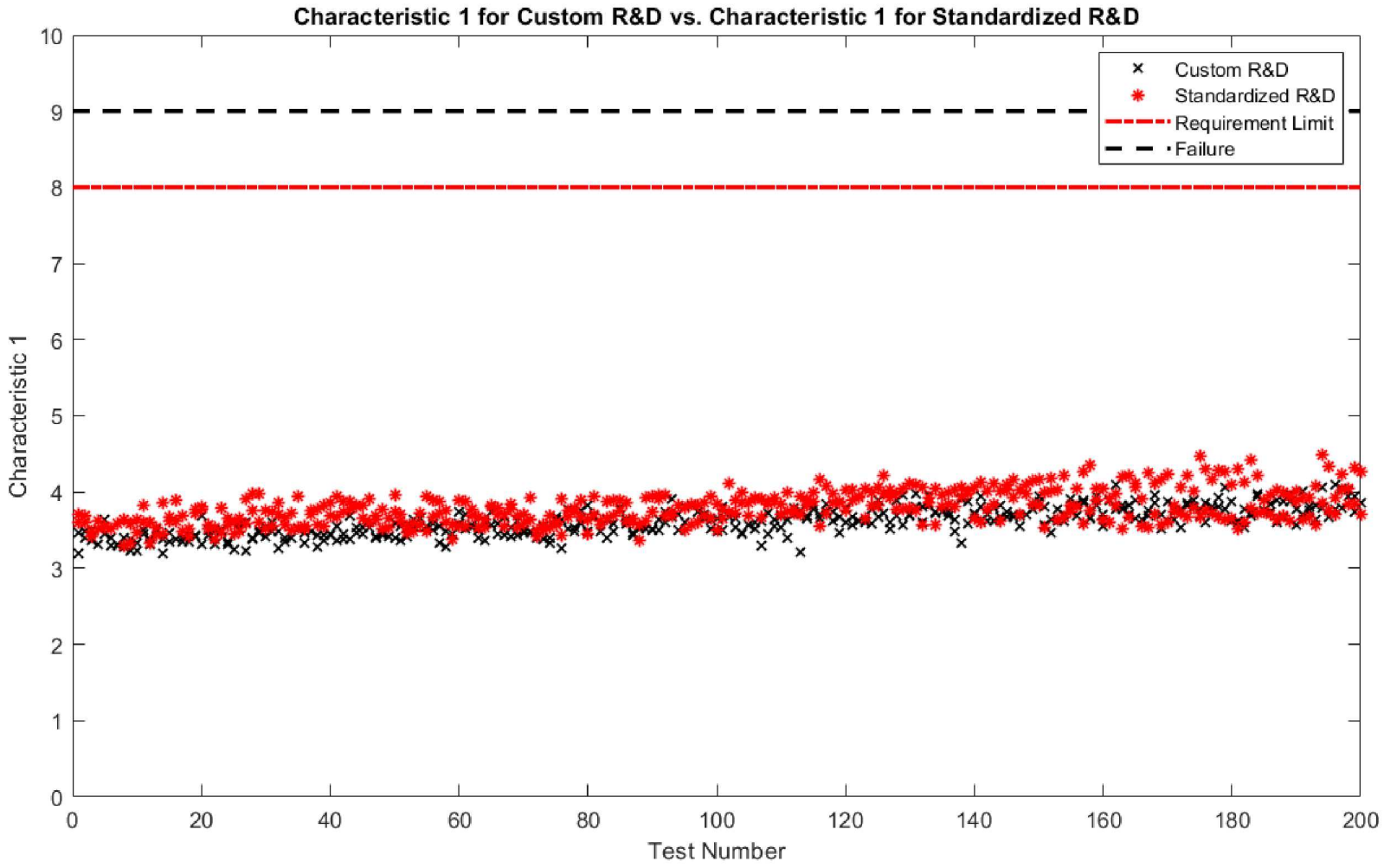
$$t = \frac{(\overline{X_1}) - (\overline{X_2}) - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

$$Level\ of\ confidence$$

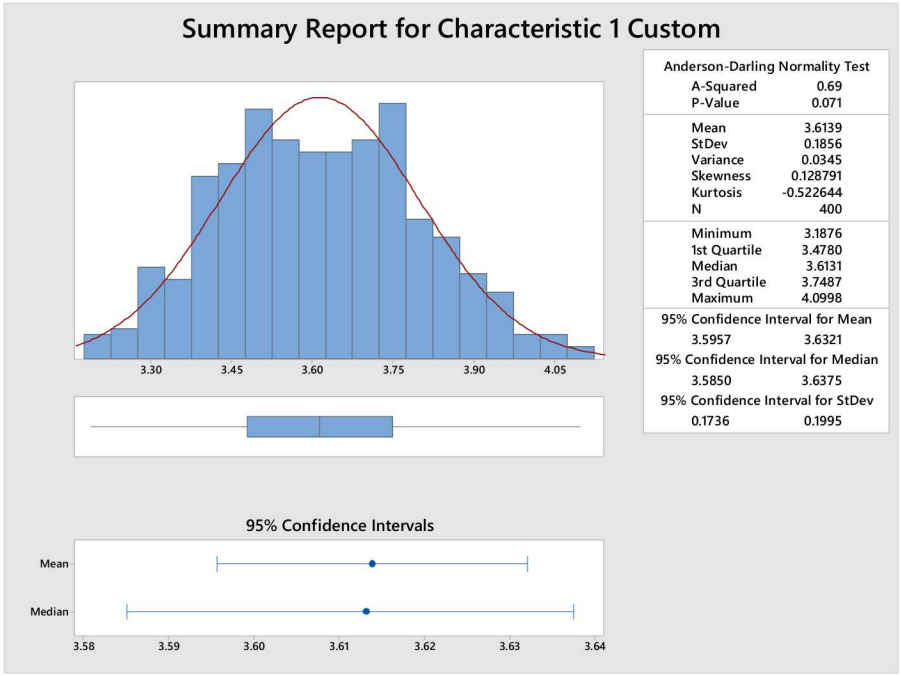
$$= (\overline{X_1} - \overline{X_2}) - t_{\alpha/2}\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}} \leq \mu_1 - \mu_2$$

$$\leq (\overline{X_1} - \overline{X_2}) + t_{\alpha/2}\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}$$

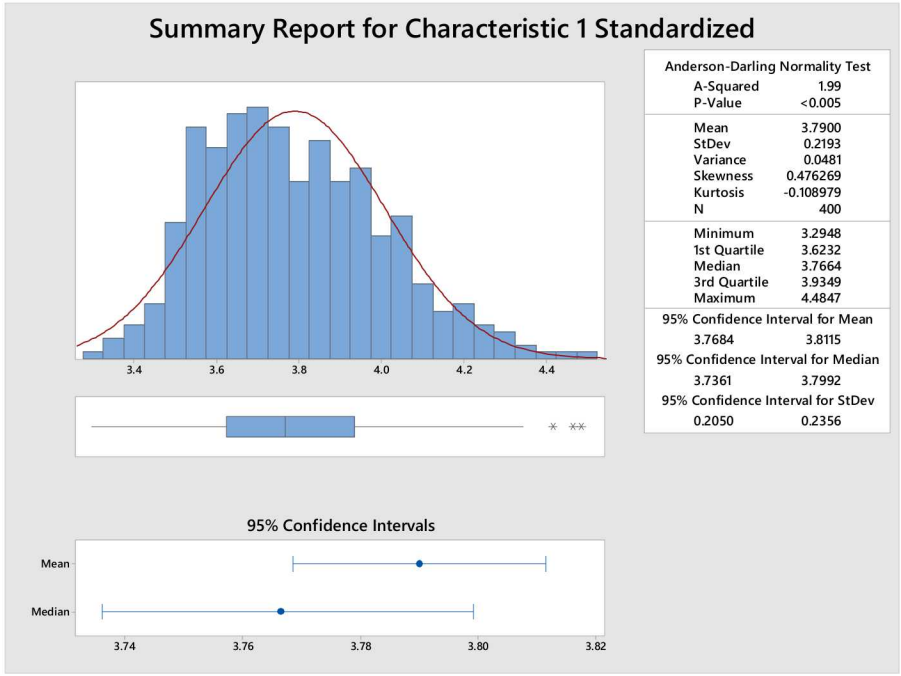
Characteristic 1



Characteristic 1

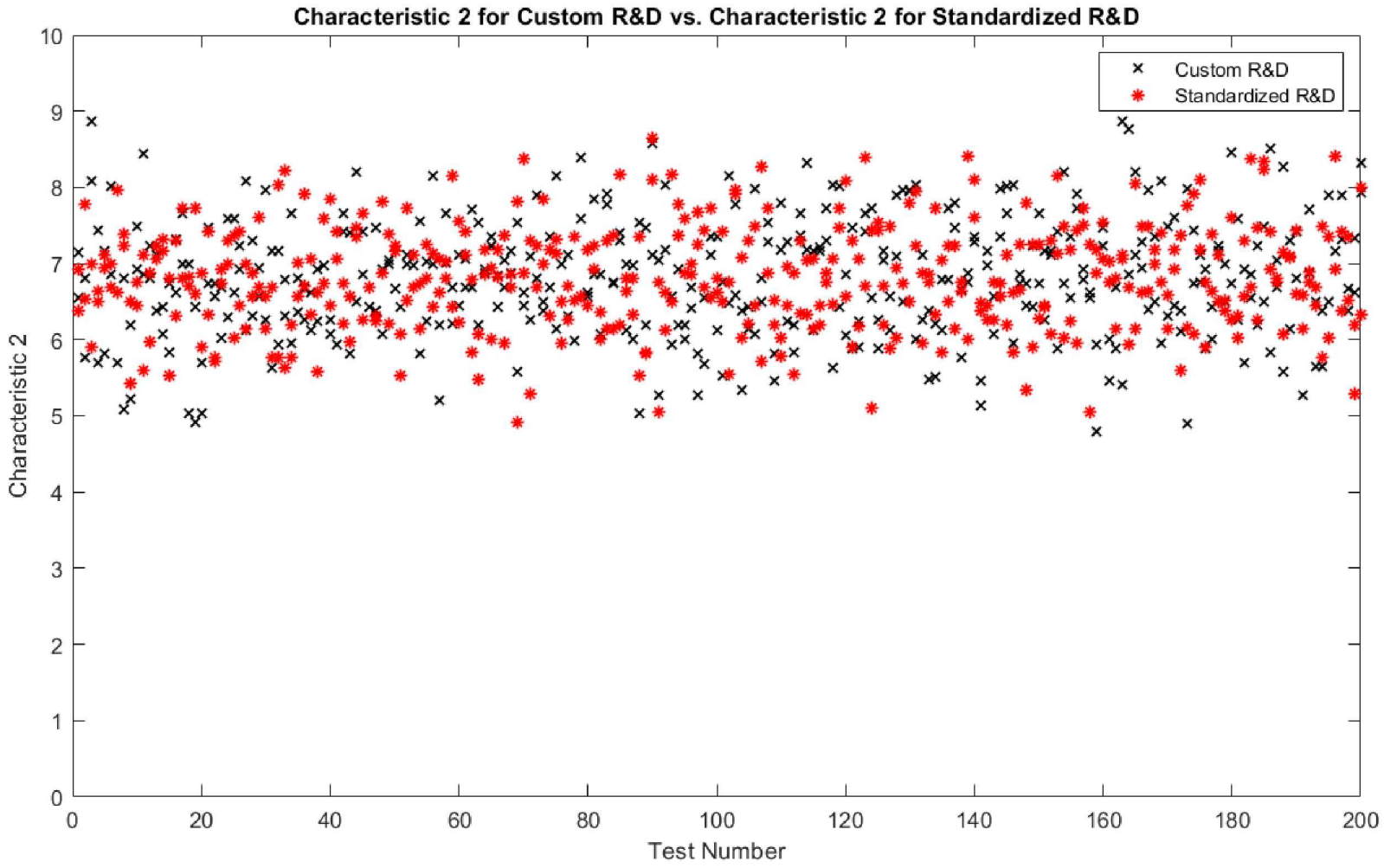


Anderson-Darling Normality Test	
A-Squared	0.69
P-Value	0.071
Mean	3.6139
StDev	0.1856
Variance	0.0345
Skewness	0.128791
Kurtosis	-0.522644
N	400
Minimum	3.1876
1st Quartile	3.4780
Median	3.6131
3rd Quartile	3.7487
Maximum	4.0998
95% Confidence Interval for Mean	
3.5957	3.6321
95% Confidence Interval for Median	
3.5850	3.6375
95% Confidence Interval for StDev	
0.1736	0.1995



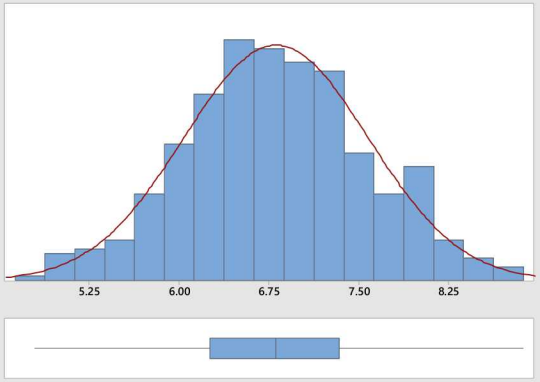
Anderson-Darling Normality Test	
A-Squared	1.99
P-Value	<0.005
Mean	3.7900
StDev	0.2193
Variance	0.0481
Skewness	0.476269
Kurtosis	-0.108979
N	400
Minimum	3.2948
1st Quartile	3.6232
Median	3.7664
3rd Quartile	3.9349
Maximum	4.4847
95% Confidence Interval for Mean	
3.7684	3.8115
95% Confidence Interval for Median	
3.7361	3.7992
95% Confidence Interval for StDev	
0.2050	0.2356

Characteristic 2

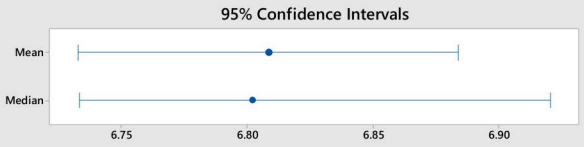


Characteristic 2

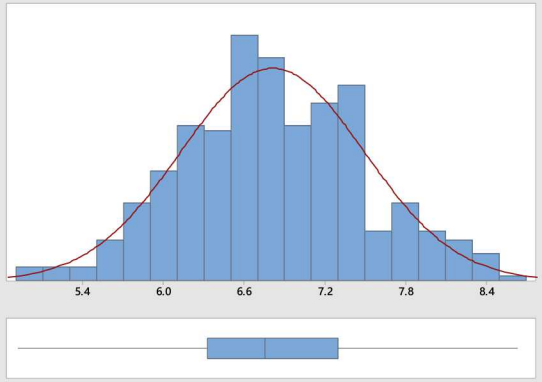
Summary Report for Characteristic 2 Custom



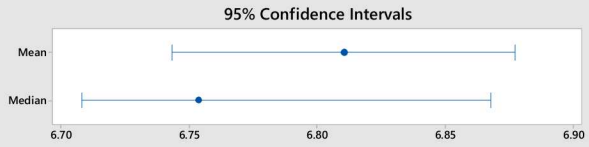
Anderson-Darling Normality Test	
A-Squared	0.18
P-Value	0.921
Mean	6.8083
StDev	0.7701
Variance	0.5931
Skewness	0.007637
Kurtosis	-0.195891
N	400
Minimum	4.7886
1st Quartile	6.2568
Median	6.8018
3rd Quartile	7.3344
Maximum	8.8742
95% Confidence Interval for Mean	
6.7326	6.8840
95% Confidence Interval for Median	
6.7331	6.9204
95% Confidence Interval for StDev	
0.7202	0.8276



Summary Report for Characteristic 2 Standardized



Anderson-Darling Normality Test	
A-Squared	0.27
P-Value	0.674
Mean	6.8105
StDev	0.6830
Variance	0.4665
Skewness	0.044838
Kurtosis	-0.163534
N	400
Minimum	4.9118
1st Quartile	6.3234
Median	6.7537
3rd Quartile	7.2958
Maximum	8.6376
95% Confidence Interval for Mean	
6.7433	6.8776
95% Confidence Interval for Median	
6.7079	6.8679
95% Confidence Interval for StDev	
0.6387	0.7339



Method

μ_1: mean of Characteristic 2 Custom
μ_2: mean of Characteristic 2 Standardized
Difference: $\mu_1 - \mu_2$

Equal variances are assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
Characteristic 2 Custom	400	6.808	0.770	0.039
Characteristic 2 Standardized	400	6.810	0.683	0.034

Estimation for Difference

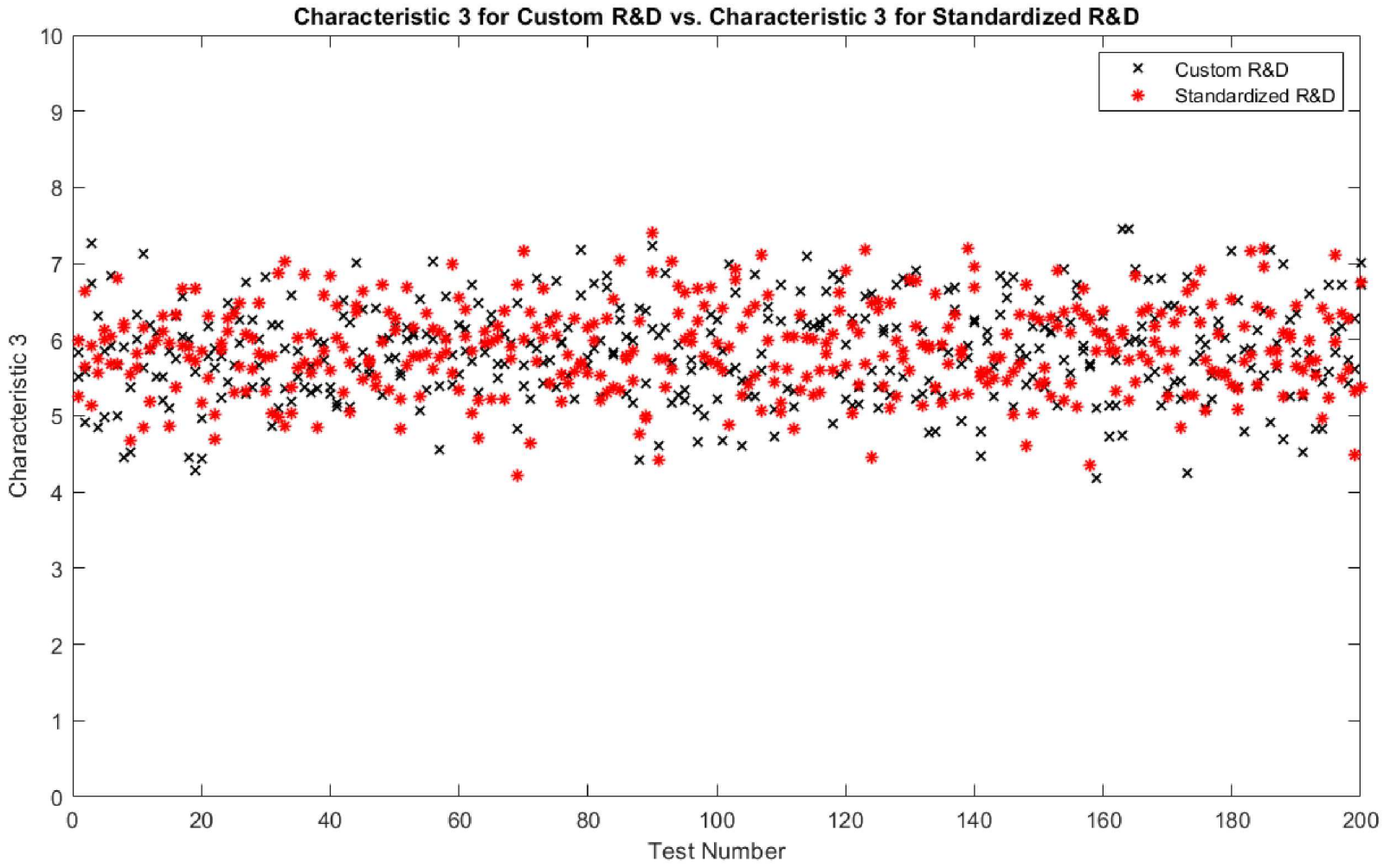
Difference	Pooled StDev	95% CI for Difference
-0.0021	0.7279	(-0.1032, 0.0989)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-0.04	798	0.967

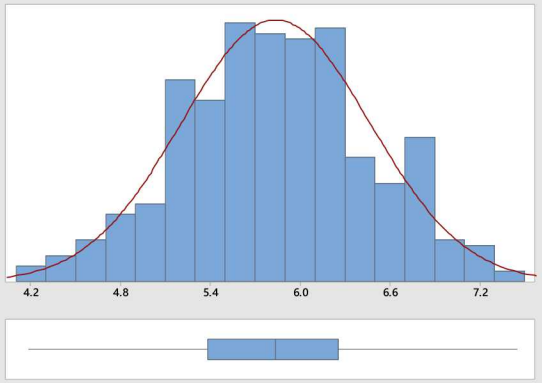
Characteristic 3



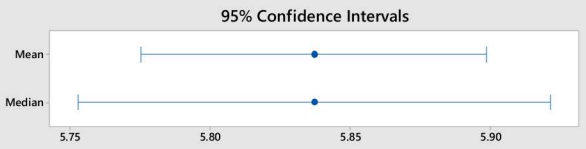
Characteristic 3

Sandia National Laboratories

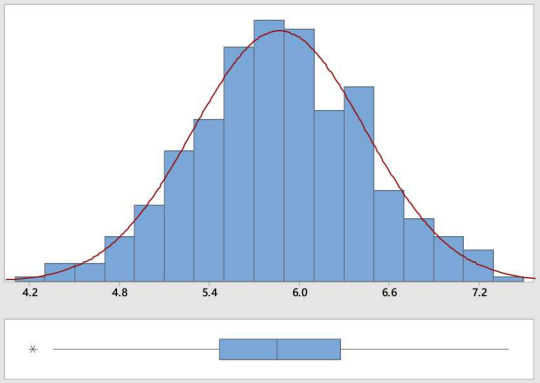
Summary Report for Characteristic 3 Custom



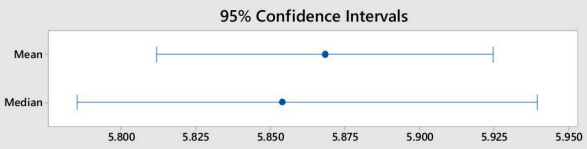
Anderson-Darling Normality Test	
A-Squared	0.27
P-Value	0.683
Mean	5.8370
StDev	0.6299
Variance	0.3968
Skewness	-0.013285
Kurtosis	-0.285556
N	400
Minimum	4.1854
1st Quartile	5.3820
Median	5.8371
3rd Quartile	6.2584
Maximum	7.4551
95% Confidence Interval for Mean	
5.7751	5.8989
95% Confidence Interval for Median	
5.7528	5.9213
95% Confidence Interval for StDev	
0.5891	0.6769



Summary Report for Characteristic 3 Standardized



Anderson-Darling Normality Test	
A-Squared	0.20
P-Value	0.882
Mean	5.8685
StDev	0.5744
Variance	0.3299
Skewness	0.019265
Kurtosis	-0.139913
N	400
Minimum	4.2191
1st Quartile	5.4705
Median	5.8539
3rd Quartile	6.2753
Maximum	7.4045
95% Confidence Interval for Mean	
5.8120	5.9249
95% Confidence Interval for Median	
5.7850	5.9397
95% Confidence Interval for StDev	
0.5371	0.6172



Method

μ_1: mean of Characteristic 3 Custom
μ_2: mean of Characteristic 3 Standardized
Difference: $\mu_1 - \mu_2$

Equal variances are assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
Characteristic 3 Custom	400	5.837	0.630	0.031
Characteristic 3 Standardized	400	5.868	0.574	0.029

Estimation for Difference

Difference	Pooled StDev	95% CI for Difference
-0.0315	0.6028	(-0.1151, 0.0522)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-0.74	798	0.460

Business Impact

Sandia National Laboratories

Accounted hours spend in R&D for the SM based on the Custom Process

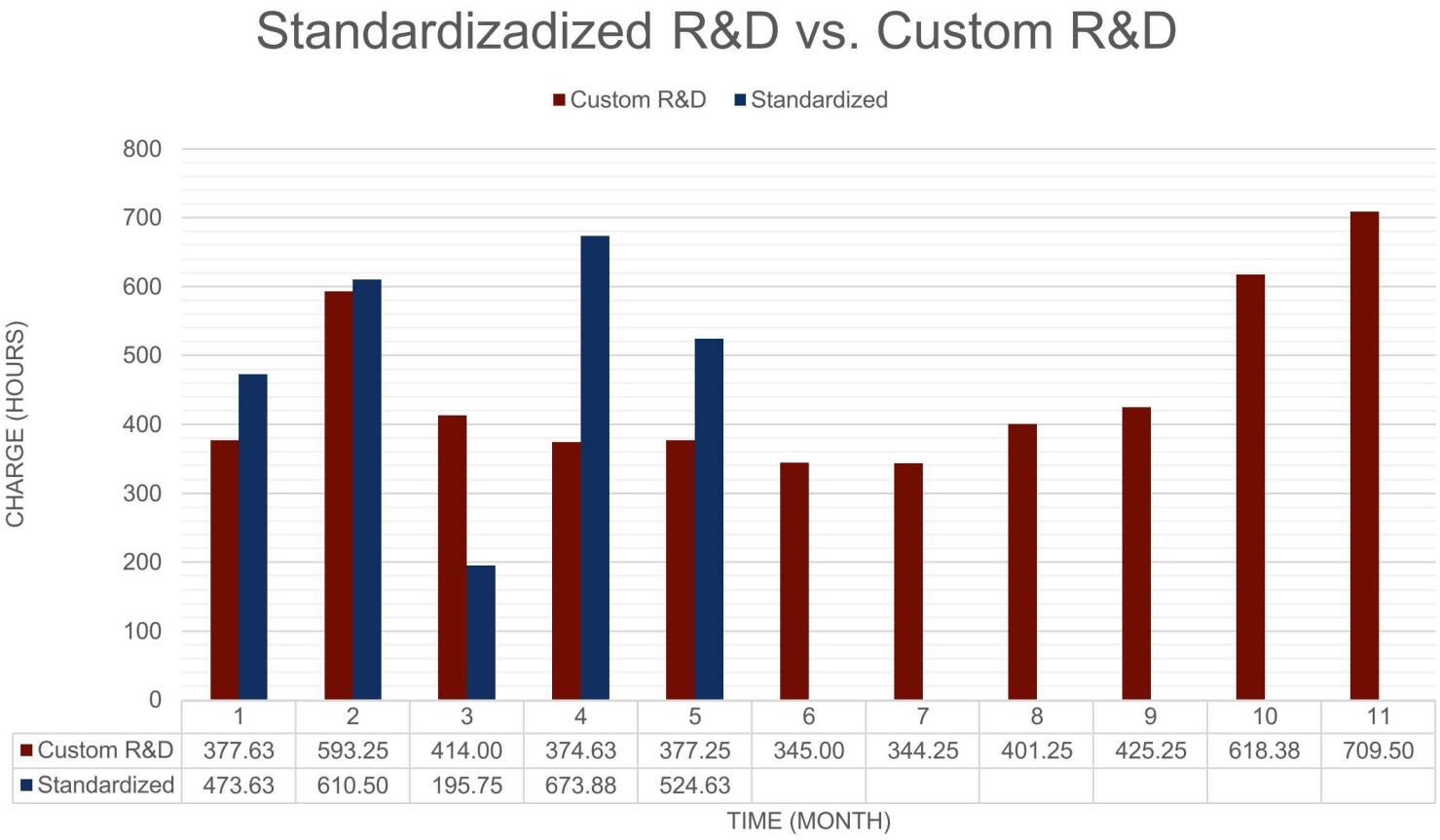
	Time Schedule	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	∑ Total
Design													
	PRODUCT DESIGN ENGINEER	37.50	3.00	24.00	9.75	12.00	11.25	3.75	18.00	16.50	4.50	140.25	280.50
	R&D S&E, ELECTRICAL ENGINEERING	19.50	42.00	31.50	24.00	40.50	7.50	33.00	139.50	37.50	34.50	10.50	420.00
	R&D S&E, MATERIALS SCIENCE	3.00	58.50	22.50	18.00	34.50	37.50	10.50	7.50	24.00	9.00	18.00	243.00
	R&D S&E, MECHANICAL ENGINEERING	58.50	81.00	24.75	39.00	46.50	45.00	48.00	55.50	37.88	147.00	65.63	648.75
	R&D S&E, SYSTEMS ENGINEERING	22.50	0.00	0.00	0.00	0.00	12.00	21.00	7.50	16.50	21.00	100.50	201.00
Fabrication													
	ENGINEERING SUPPORT TECHNOLOGIST	0.00	0.00	0.00	0.00	0.00	37.50	57.00	24.00	31.50	22.50	46.50	219.00
	MECHANICAL TECHNOLOGIST	49.50	108.00	19.50	0.00	12.00	0.00	0.00	0.00	0.00	0.00	0.00	189.00
	PRODUCT DESIGN ENGINEER	26.63	6.00	0.00	7.50	5.25	0.00	0.00	0.00	0.00	0.00	0.00	45.38
Test													
	COMPUTER AIDED DESIGN AND DRAFTING TECHNOLOGIST	15.00	0.00	0.00	0.00	0.00	3.75	0.00	0.00	7.88	4.50	9.75	40.88
	ENGINEERING SUPPORT TECHNOLOGIST	0.00	21.00	66.75	123.00	30.75	13.50	0.00	24.00	38.25	160.50	162.00	639.75
		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	PRODUCT DESIGN ENGINEER	36.75	52.50	48.75	0.00	0.00	0.00	0.00	0.00	3.00	0.38	18.75	160.13
	R&D S&E, ELECTRICAL ENGINEERING	30.75	58.88	90.00	52.13	79.50	96.00	62.25	48.00	111.00	144.00	82.13	854.63
	R&D S&E, MECHANICAL ENGINEERING	49.50	108.00	19.50	0.00	0.00	0.00	0.00	3.75	30.75	0.00	0.00	211.50
	R&D S&E, SYSTEMS ENGINEERING	0.00	0.00	6.00	1.50	0.00	6.00	0.00	0.00	6.00	18.00	34.50	72.00
Project MGMT													
	PROJECT CONTROLLER	16.50	22.50	38.25	70.50	69.00	45.00	79.50	28.50	0.00	21.00	0.00	390.75
	R&D S&E, ELECTRICAL ENGINEERING	0.00	31.88	22.50	29.25	47.25	30.00	29.25	45.00	64.50	31.50	21.00	352.13
	R&D S&E, MECHANICAL ENGINEERING	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.00
Grand Total		**377.63**	**593.25**	**414.00**	**374.63**	**377.25**	**345.00**	**344.25**	**401.25**	**425.25**	**618.38**	**709.50**	***4980.38***

Business Impact

Accounted hours spend in R&D for the SM based on the Standardized Process

	Time Schedule	Month 1	Month 2	Month 3	Month 4	Month 5	∑ Total
Design							
	PRODUCT DESIGN ENGINEER	3.00	15.00	6.75	12.00	9.75	46.50
	R&D S&E, ELECTRICAL ENGINEERING	46.50	55.50	28.50	60.00	30.00	220.50
	R&D S&E, MATERIALS SCIENCE	0.00	12.00	16.50	25.50	6.00	60.00
	R&D S&E, MECHANICAL ENGINEERING	96.75	104.25	27.00	78.75	33.00	339.75
	R&D S&E, SYSTEMS ENGINEERING	7.50	0.00	0.00	10.50	24.00	42.00
Fabrication							
	ENGINEERING SUPPORT TECHNOLOGIST	0.00	0.00	0.00	40.50	8.25	48.75
	MECHANICAL TECHNOLOGIST	23.63	0.00	0.00	10.88	0.00	34.50
	PRODUCT DESIGN ENGINEER	2.25	62.25	0.00	17.25	0.00	81.75
Test							
	COMPUTER AIDED DESIGN AND DRAFTING TECHNOLOGIST	5.25	21.75	9.38	14.25	81.38	132.00
	ENGINEERING SUPPORT TECHNOLOGIST	43.50	19.50	0.00	118.50	99.00	280.50
		0.00	0.00	0.00	0.00	0.00	0.00
	PRODUCT DESIGN ENGINEER	0.00	10.50	12.38	21.75	0.00	44.63
	R&D S&E, ELECTRICAL ENGINEERING	43.50	75.75	6.00	87.00	105.75	318.00
	R&D S&E, MECHANICAL ENGINEERING	16.50	51.00	28.50	39.00	37.50	172.50
	R&D S&E, SYSTEMS ENGINEERING	31.50	16.50	0.00	0.00	21.00	69.00
Project MGMT							
	PROJECT CONTROLLER	49.50	50.25	25.50	57.00	28.50	210.75
	R&D S&E, ELECTRICAL ENGINEERING	43.50	48.75	9.75	34.50	4.50	141.00
	R&D S&E, MECHANICAL ENGINEERING	60.75	67.50	25.50	46.50	36.00	236.25
Grand Total		**473.63**	**610.50**	**195.75**	**673.88**	**524.63**	***2478.38***

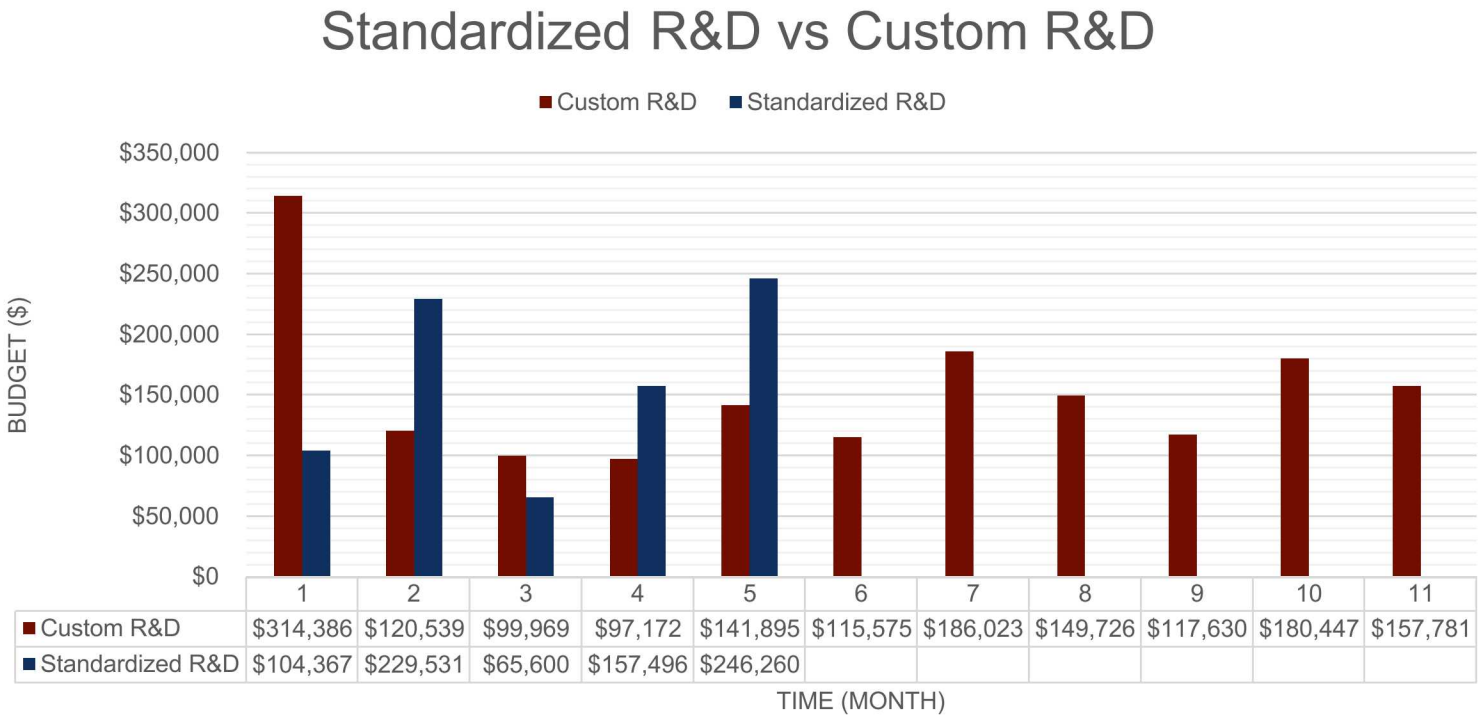
Business Impact



	1	2	3	4	5	6	7	8	9	10	11
Custom R&D	377.63	593.25	414.00	374.63	377.25	345.00	344.25	401.25	425.25	618.38	709.50
Standardized	473.63	610.50	195.75	673.88	524.63						

Business Impact

	Time Schedule	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	
Custom R&D	LABOR	$42,233	$120,533	$81,573	$82,941	$92,127	$74,514	$102,756	$110,067	$103,552	$126,690	$75,770	
	CHARGEBACKS	($463)	$6	$2,549	$795	$0	$1,420	$6,357	$0	$3,186	$8,973	$0	
	PURCHASES	$272,616	$0	$15,848	$13,437	$49,768	$39,641	$76,909	$39,660	$10,892	$44,784	$82,010	**Total Budget**
	Grand Total	**$314,386**	**$120,539**	**$99,969**	**$97,172**	**$141,895**	**$115,575**	**$186,023**	**$149,726**	**$117,630**	**$180,447**	**$157,781**	***$1,681,144***
	Time Schedule	**Month 1**	**Month 2**	**Month 3**	**Month 4**	**Month 5**							
Standardized R&D	LABOR	$100,407	$129,752	$43,924	$143,434	$188,408							
	CHARGEBACKS	$789	$2,118	$2,942	$0	$1,045							
	PURCHASES	$3,171	$97,661	$18,734	$14,062	$56,807							**Total Budget**
	Grand Total	**$104,367**	**$229,531**	**$65,600**	**$157,496**	**$246,260**							***$803,253***



Conclusion

Sandia National Laboratories

Current

- Shorter lead time
- Simplified design
- Reduced man-hours
- Reduced spending
- Funding repurposed
- More R&D time
- Less documentation

Future Work

- Explore more optimal designs
- Lack of induction regulation
- Better space configuration
- Optimize PCB surface area
- Integrate characterization circuits
- Explore 3D print options

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Questions